CDF note 7143

Search for $\Lambda_b \to pK$ and $p\pi$ decays

The CDF Collaboration
URL http://www-cdf.fnal.gov
(Dated: July 26, 2004)

This note describes a search for $\Lambda_b \to pK$ and $\Lambda_b \to p\pi$. The analysis is based on an integrated luminosity of 193 pb^{-1} collected with the CDF II detector. The preliminary result is an upper limit on the Branching Ratio. We find $BR(\Lambda_b \to hh) < 22. \times 10^{-6}$ at 90% C.L.

Preliminary Results for Summer 2004 Conferences

I. INTRODUCTION

Detection of Λ_b charmless decays into hadrons is one of the challenging goals of CDF II [1]. In those decays, a quite large direct CP violation is expected [2].

This note describes a search for the decays $\Lambda_b \to pK$ and $\Lambda_b \to p\pi$ in $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV with the CDF detector at the Fermilab Tevatron. Such decays have not been seen up to now. The current upper limits on the Branching Ratios are $50. \times 10^{-6}$ on each of the decay modes [5]. Theoretical predictions are between 10^{-6} and $2. \times 10^{-6}$ [6].

The Branching Ratios $BR(\Lambda_b \to hh)$ are normalized to the Branching Ratio $BR(B_d^0 \to K\pi) = (1.74 \pm 0.15) \times 10^{-5}$ [3].

The relationship between the Branching Ratios and the number of observed events is the following:

$$\frac{\epsilon_\Lambda f_\Lambda BR(\Lambda_b \to hh)}{\epsilon_B f_B BR(B_d \to K\pi)} = \frac{N(\Lambda_b \to hh)}{N(B_d \to K\pi)}$$

where:

- N is the number of observed events (Λ_b or B_d);
- ϵ_Λ (ϵ_B) is the total efficiency (trigger, reconstruction and analysis) for observing a Λ_b (B^0); The efficiency ϵ_Λ is assumed to be the same for the two decay modes pK and $p\pi$;
- f_Λ (f_B) is the b-quark hadronization fraction for the Λ_b (B^0). We use the following values [4]: $f_\Lambda = 0.094 \pm 0.17$, $f_B = 0.397 \pm 0.0010$, $f_\Lambda/f_B = 0.25 \pm 0.04$

The number of observed $B_d \to K\pi$ decays is a fraction of the total number of $B \to h^+h^-$:

$$f = N(B_d \to K\pi)/N(B \to h^+h^-)$$

Therefore

$$BR(\Lambda_b \to hh) = \frac{N(\Lambda_b \to hh)}{A}$$

where

$$A = \frac{\epsilon_\Lambda f_\Lambda f N(B \to h^+h^-)}{\epsilon_B f_B BR(B_d \to K\pi)}$$

We call A the acceptance.

II. DATA SAMPLE & EVENT SELECTION

The analysis is performed on data taken with the CDFII detector between February 2002 and September 2003, corresponding to an integrated luminosity of $193\,\mathrm{pb}^{-1}$.

The data are collected with the “Two-Track Trigger”, which selects events containing track pairs coming from secondary vertexes.

CDF uses a three-level trigger. At first level, the XFT (eXtremely Fast Tracker) reconstructs and selects tracks with transverse momentum $p_T > 2\,\mathrm{GeV/c}$.

At the second level the SVT (Silicon Vertex Tracker) measures the track impact parameters (d_0) and selects tracks pairs coming from secondary vertexes by cutting on d_0.

At the third level a complete event reconstruction is performed, and the level 1 and level 2 requirements are confirmed.

In order to look for $\Lambda_b \to pK$ and $p\pi$ decays, the invariant mass of track pairs is calculated by assigning the mass of the π to both tracks. The reason is that such assignment maximizes the separation between the peaks of the $B \to hh$ and the Λ_b decays in the mass spectrum.

A. Optimized Search

The selection optimization has been performed using the estimator defined in [7]. This estimator provides optimal cuts which are good for signal measurements and for setting an upper limit on it.

The optimization has been performed hiding the signal region in the invariant mass spectrum and using only events with even trigger numbers, i.e. 50% of the total sample. In fact, we want to avoid using the same sample for both optimization and background calculation, since we can introduce a statistical bias due to fluctuations.

For each set of cuts, the value of the background has been obtained by fitting the sidebands in the invariant mass spectrum and integrating the fitted function in the signal region.

The reconstruction efficiency for the signal has been evaluated using a Monte Carlo.

III. BACKGROUNDS

The background in this analysis is given by track pairs which accidentally have an invariant mass close to the mass of the Λ_b ("combinatorial background") and the tail from the $B \to hh$ signal.

The background has been calculated by fitting the invariant mass spectrum and interpolating in the signal region. Only events with odd trigger numbers were used.

In order to evaluate the systematic uncertainty due to the shape of the background, different functions have been used. Such a systematic affects the number of $B \to hh$ events used for normalization.

The value for the expected background in the signal region is:

$$b = 772 \pm 31$$

where the error includes both the statistical and systematic errors.

IV. SYSTEMATIC UNCERTAINTIES

Systematic uncertainties on the acceptance come from the following sources:

- shape of the background in the signal region of the invariant mass spectrum (it affects the expected background);
- the number of $B \to hh$ reconstructed decays is also affected by the shape of the background;
- relative Branching Fractions of $\Lambda_b \to pk$ and $\Lambda_b \to p\pi$, since the two decay modes have a different reconstruction efficiency;
- difference between the invariant masses predicted by Monte Carlo and reconstructed in the data;
- difference between the invariant mass resolutions predicted by Monte Carlo and reconstructed in the data;
- uncertainties in the B and Λ_b lifetimes;
- different Level 1 trigger efficiencies for Protons, Kaons and Pions, because of the different specific ionization;
- different p_T spectra for B and Λ_bs;
- uncertainty in the Branching Ratio $BR(B \to K\pi)$;
- uncertainty in the production fractions of B and Λ_b.

In table I all the systematic errors are listed.

$B \to h^{\pm}h^{\mp}$	
Shape of the background	5.7%
Background	
Shape of the background	3.3%
Relative Λ_b/B Efficiency	
$\Lambda_b \to p\pi/\Lambda_b \to pK$ ratio	2.3%
Window position	1.2%
Window width	9%
Lifetime	3.6%
L1 trigger efficiency for protons	6%
$p_T(\Lambda_b)$	17%
Overall systematic	21%
$\mathrm{BR}(B_d \to K\pi)$	8.6%
f_{Λ_b}/f_B	16%

TABLE I: Summary of the systematic errors.

$N(B \to hh)$	726 ± 82
$\epsilon_B/\epsilon_\Lambda$	1.77 ± 0.37

TABLE II: Measured quantities that enter in the Λ_b acceptance.

V. RESULTS

In figure 1 we show the full mass spectrum with the search window. The total number of events in the signal region of the mass spectrum is

$$N = 767$$

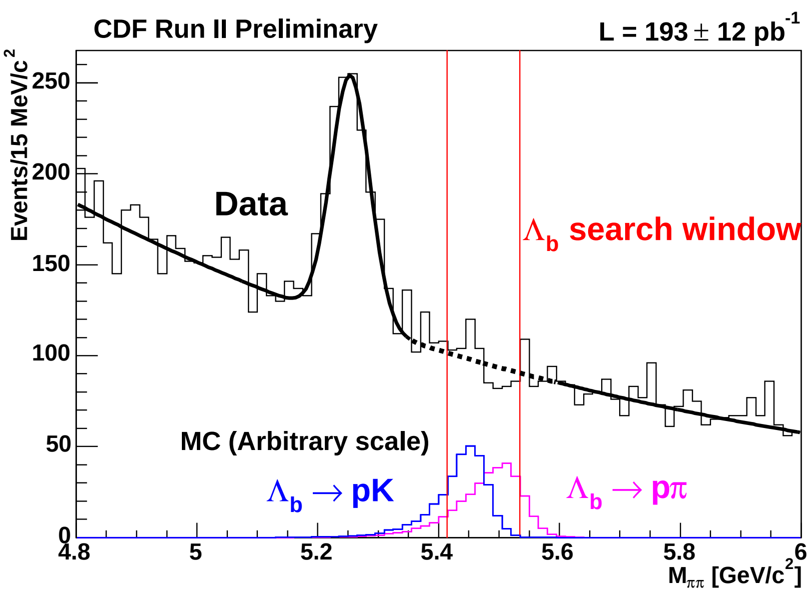

FIG. 1: Mass distribution of data with full statistics. The function is the one fitted using only odd events. The continuous line shows the part of the function that has been fitted while the dashed line cover the part of the mass distribution that has not been used for the fit. The two red lines define the search window. The two MC plot are the mass distributions for the two decay modes using an arbitrary scale.

The quantity

$$f = \frac{N(B \to K\pi)}{N(B \to h^+h^-)} = 0.59 \pm 0.04$$

has been calculated using the fitting procedure used in [8].

The ratio between the number of $\Lambda_b \to hh$ and the branching ratio $BR(\Lambda_b \to hh)$ depends on the number of events of $B \to hh$ and the relative efficiency $\epsilon_\Lambda/\epsilon_B$. These values are reported in table II. The measured value of the ratio is:

$$A = \frac{N(\Lambda_b \to hh)}{BR(\Lambda_b \to hh)} = (3.5 \pm 1.1) \cdot 10^6$$

The error includes both statistical and systematic errors.

Using a Bayesian method uniform prior distribution, we find that the upper limit on the number of signal events s is:

$$s < 75$$

at 90% Confidence Level.

The upper limit on the Branching Ratio is:

$$BR(\Lambda_b \to hh) < 22 \cdot 10^{-6} \quad (90\% C.L.)$$

Acknowledgments

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Bundesministerium fuer Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Particle Physics and Astronomy Research Council and the Royal Society, UK; the Russian Foundation for Basic Research; the Comision Interministerial de Ciencia y Tecnologia, Spain; and in part by the European Community's Human Potential Programme under contract HPRN-CT-20002, Probe for New Physics.

[1] F. Abe, et al., Nucl. Instrum. Methods Phys. Res. A **271**, 387 (1988); D. Amidei, et al., Nucl. Instum. Methods Phys. Res. A **350**, 73 (1994); F. Abe, et al., Phys. Rev. D **52**, 4784 (1995); P. Azzi, et al., Nucl. Instrum. Methods Phys. Res. A **360**, 137 (1995); The CDFII Detector Technical Design Report, Fermilab-Pub-96/390-E
[2] I. Dunietz, Z. Phys. C 56 (1992) 129.
[3] *Review of Particle Physics*, K. Hagiwara *et al.*, Physical Review **D 66** 010001 (2002)
[4] `http://www.slac.stanford.edu/xorg/hfag/osc/winter_2004/index.html#FRAC`
[5] D. Buskukic et al., Phys. Lett. **B 384** (1996) 471-480.
[6] R. Mohanta et al., Phys. Rev. **D 63**:074001 (2001).
[7] G. Punzi, Optimization of searches for new signals, physics/0308063, `http://www.arxiv.org/ps/physics/0308063`.
[8] "Measurement of the relative fractions and of direct CP asymmetries in the $B^0 \to h^\pm h'^\mp$ signal," CDF Note 7142.